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An Experimental Turbidity Probe Installation

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Abstract

Turbidity probes were operated at five sites in the Cariboo Mountains during the 1994 and 1995 field seasons in order to monitor the effects of forest practices on streamwater quality. Turbidity was recorded on data loggers for later use in extending suspended sediment data derived from gravimetric analysis of water samples. At each site, the turbidity probe was mounted on a float held in place from above the channel in order to avoid problems associated with high power streams. This installation method allowed water, floating debris, and bedload to pass underneath without damage to the probe, however, probes installed this way were subject to false high readings due to bubbles under some conditions. Interference due to bubbles was reduced by sub-sampling of datalogger readings. However, substantial reduction of bubble interference is expected to be achieved in a modified version by increasing the depth of the sensor below the water surface.

Introduction

Suspended sediment was monitored at a number of locations near Quesnel Lake, B.C. during the 1994 and 1995 field seasons due to concerns about the effects of forestry activities on fish habitat. Turbidity probes and dataloggers were operated five of the sites in order to extend the suspended sediment records by the use of calibrations between suspended sediment and turbidity.

The streams we monitored are subject to sediment, debris, and flow conditions which present problems for a turbidity probe installed on a fixed structure in the channel bed. Therefore, we suspended probes from above, which did not require any structure attached to the channel bed or banks. The purpose of this paper is to describe the installation method and to evaluate its performance.

Problems Associated with Turbidity Probe Installation

We considered three types of problems associated with the installation of turbidity probes at our sites - installation logistics, physical security of the probe, and data errors due to sensor location.

All of our sites are on streams greater than 10 metres wide with alluvial beds and banks composed of gravel and larger material. Only one of five sites had a pre-existing structure in the channel on which a turbidity probe could be conveniently mounted (the one shown in Figure 2). At most of the sites, finding a physically secure and otherwise suitable location to drive a post into the bed on which to mount the probe would have been problematic. Installation options were limited at two stations because the they were accessible only by helicopter.

Another concern with a probe being mounted on a fixed structure at our sites was the possibility of interference from obstacles within the detection volume of the sensor. In clear water, the probe we are using (OBS-3 from D&A Instruments) can generate erroneously high readings from objects that are up to about 15 cm from the sensor along its optical axis. The sensitivity of the sensor decreases fairly rapidly at angles away from this axis, however, positioning the sensor high enough above the stream bed and deep enough below the water surface to avoid undesirable reflections can be restrictive. This tends to introduce tradeoffs between probe security, installation convenience, and the avoidance of false high readings.

Overhead Suspension System

In order to reduce the problems described above, we developed a prototype overhead suspension system which can be used to mount a turbidity probe as well as a pump sampler intake. The probe is installed with its sensor pointing down on the underside of a float made of PVC pipe, as shown in Figure 1. The float is attached to the end of a PVC pipe supported from above by either a rope and pulley system or a bridge, as shown in Figure 2 which is on Moffat Creek near the town of Horsefly.

At our sites, the main advantages of this installation method are:

- All components can be easily transported and installed by one person if necessary.
- The probe or sampler intake can be installed, serviced, or removed during any streamflow conditions.
- Nothing is installed in the channel bed or banks, thereby reducing the chance of the probe being buried, damaged, or washed away during periods of high streamflow or debris movement.
- The position of the float can be adjusted across the channel at any time to accomodate changing flows.

- The turbidity probe and sampler intake are assured of sampling only suspended sediment (as opposed to bed load) as long as there is a sufficient depth of water under the float.

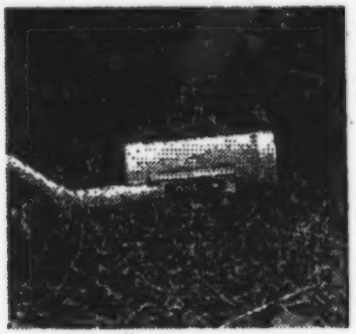

Figure 1. Turbidity probe and float assembly on stream bank before installation.

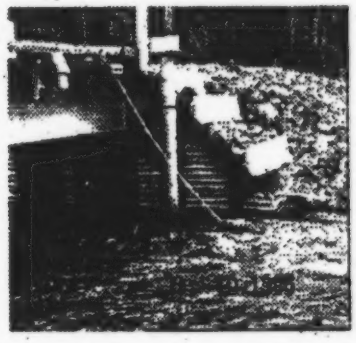

Figure 2. Float and turbidity probe mounted on end of plastic pipe attached to bridge at Moffat Creek. Probe is oriented horizontally with sensor pointing down. Note datalogger suspended from bridge railing and Water Survey of Canada stilling well.

At some locations, the high visibility of this installation may be undesirable due to the potential for vandalism, but that has not been a problem at our sites. The one problem we did have was interference from bubbles causing erroneously high readings under some conditions. Bubbles were a problem at times of higher water velocities at Moffat Creek due to the relatively shallow depth of the sensor. Using an underwater video camera, we documented bubbles in the immediate vicinity of the sensor as shown in Figure 3.

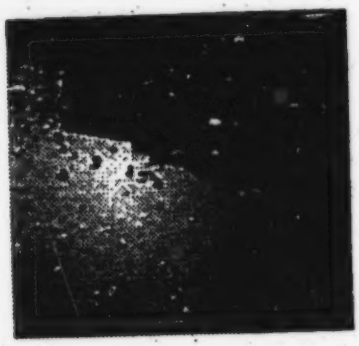

Figure 3. Turbidity probe sensor underwater at a depth of about 10 cm at Moffat Creek. Downstream is to the left. Bubbles range in size up to a few millimetres.

Errors due to bubbles occured at water velocities of about a metre per second or more at the Moffat Creek site. However, the underwater imaging and manual turbidity readings taken at various depths with a hand held probe indicated that bubbles decreased rapidly with increasing depth below the surface. This provides an opportunity for decreasing bubble related errors in the future by increasing the sensor depth.

Response of Sensor to Bubbles

Early in the monitoring program we noticed that when bubbles were present, they caused high frequency fluctuations in apparent turbidty readings. A test in an aquarium indicated that this is probably because the probe responds most strongly to the highly variable number of bubbles that happen to be within a centimetre or less of the sensor at any given moment. Therefore, the dataloggers were programmed to record the minimum, average, and maximum of 10 readings taken over a period of about 2 seconds at every sampling time (every 15 minutes), instead of recording a single instantaneous reading. The minimum of this sample is considered to be a better approximation of actual turbidity because bubbles caused only positive errors.

Figure 4 shows the minimum and maximum sampled turbidities (as described above) versus time on the afternoon of May 10, 1995 at Moffat Creek when the images in Figures 2 and 3 were made. There was no obvious change in discharge between 1200 and 1630 hrs when we conducted tests at the site and turbidity measured in grab samples in a cup type turbidimeter (LaMotte Model 2008) was consistently 18 NTU during this period. However, turbidity readings from the probe fluctuated between 18 and 48 NTU during this period. Even minimum turbidity readings from sub-sampling ranged from 18 to 45 NTU.

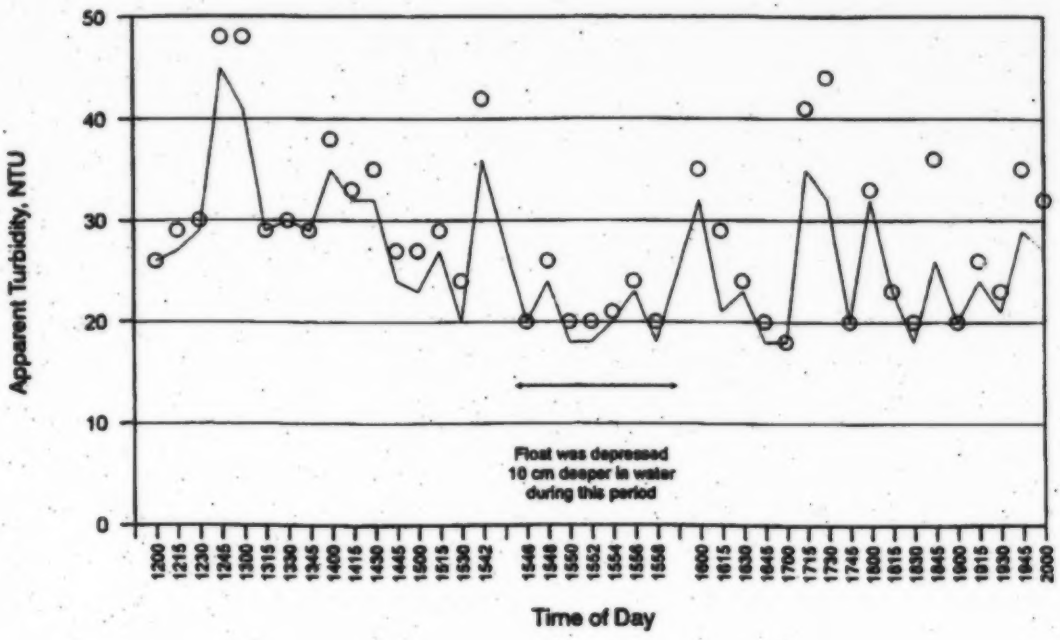

Figure 4. "Apparent" turbidity recorded from the float mounted probe in Moffat Creek on May 10th, 1995 during the tests described above. The minimum and maximum (solid line and circles) of 10 readings are plotted at each sampling time.

Bubbles are most abundant near the surface so we tested the effect of OBS-3 sensor depth on apparent turbidity in two different ways. Firstly, we forced the float down about 10 cm deeper than its normal position and recorded turbidity at two minute intervals on the datalogger between 1546 and 1558 hrs. This yielded minimum turbidity readings between 18 and 24 NTU as shown in Figure 4. Secondly, we measured turbidity with a separate hand held OBS-3 probe at depths of 20 and 40 cm next to the floating probe. Readings recorded manually over a one minute period ranged from 16 to 26 NTU at 20 cm depth and 17 to 19 NTU at 40 cm depth. These results show that the floating probe was subject to bubble interference and that this interference decreased rapidly with depth.

Calibration Between Suspended Sediment and Turbidity

Water samples for analysis of suspended sediment concentration were collected at intervals throughout the field season with a DH-59 depth integrating sampler suspended from a truck mounted boom. Each observation of suspended sediment concentration at the Moffat Creek site was obtained from the average of three water samples collected across the channel by this method. Figures 5 and 6 show the scattergrams of suspended sediment concentration versus turbidity at Moffat Creek and at a similar installation on the Horsefly River for the 1995 field season (April through October).

The calibration for the Horsefly River is reasonably good at higher sediment concentrations, however, it is poor for Moffat Creek. Explanations for the poor relationship from Moffat Creek are largely provided by noting the dates of the samples represented by outlying points on the scattergram.

On May 2, May 19, and August 15 discharge was relatively high in Moffat Creek and suspended sediment concentration was relatively low. It is suspected that this situation maximizes bubble interference because bubbles can cause the greatest proportional errors when actual turbidity is low.

Conditions on September 19 and September 26 were quite different. On those dates discharge was low and bubbles would not have been a problem. However, the water had warmed up and algae growth was rapid. The sensor should have been cleaned weekly at that time of the year but but on those dates the probe had not been cleaned for two weeks or more resulting in erroneously high turbidity readings due to "bio-fouling".

The relatively good calibration between suspended sediment concentration and turbidity at the Horsefly River station was fortuitous. The turbidity probe in the Horsefly sat a little deeper in the water than the one at Moffat Creek due to a greater weight of PVC pipe suspended from above and the float at that site had a slightly more streamlined design. The Horsefly River probe was also subject to considerably less bio-fouling than the Moffat Creek probe due to lower water temperatures.

Discussion and Conclusion

At our sites, the overhead suspension system has significant advantages over other methods of installing a turbidity probe. However, the advantages of this system are not applicable to all streams. The sites where we would recommend that it be considered are on those streams with sufficiently high energy to damage, bury, or wash out a structure to which the probe would be attached. The one disadvantage of this system was interference from bubbles, which we expect to to reduce in an improved version of the float. An unexpected advantage of this installation method is that the turbidity probe is less susceptible to false high readings from sunlight because the sensor points down instead of sideways.

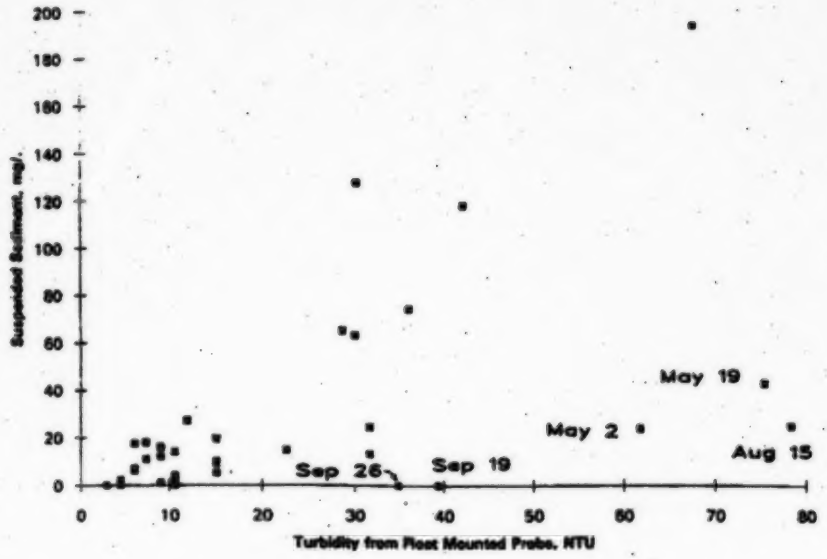

Figure 5. Suspended sediment concentration versus turbidity measured by the float mounted probe on Moffat Creek.

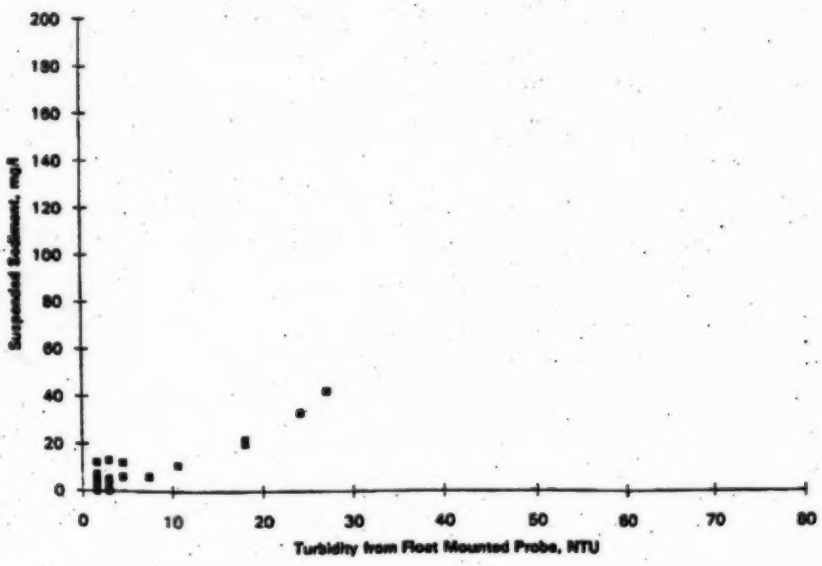

Figure 6. Suspended sediment concentration versus turbidity measured by the float mounted probe on the Horsefly River.

A very different turbidity probe installation has been developed for use in the Tsitika River by Environment Canada. It consists of a heavy steel plate with a debris deflector resting on the channel bed through which the turbidity probe is mounted from below. This method is reported to withstand high flows and does not experience bubble interference. However, installation of the plate and access to the probe may be impractical except at low flows (Ed Mayert, Environment Canada, pers. comm. 1995).

Important factors to consider in the installation of a turbidity probe are the power of the stream being monitored, its debris load, the availability of existing structures in the channel, the lifespan of the monitoring program, the resources available at the time of installation, ease of access to the site, and the cost of a replacement turbidity probe.

In contrast to the streams which we are monitoring, the most appropriate method for installing a turbidity probe in a small, low energy stream may be as simple as attaching it to a steel post driven into the channel bed. However, our concern about installing a turbidity probe in a high energy stream using this method is justified by our experience with the installation of intakes for automatic water samplers. In 1994, our two pumping samplers were put out of action by high streamflows. One sampler intake was washed away and the other was buried in sediment. Both intakes had been attached to steel re-bar that was driven into the channel bed. In 1995, we mounted the intakes to the floats which held the turbidity probes and they performed well during high flows. The advantages of installing a pump sampler intake on a float are the same as those for a turbidity probe. Disadvantages are the greater length of intake hose required and the possibility of cross contamination between samples.

In 1996 we plan to install modified floats at our sites. We expect the new design to reduce interference from bubbles without sacrificing the benefits of the overhead suspension system.